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1988 REPORT ON BRIDGE DECK WATERPROOFING

MATERIALS INFORMATION

ENGINEERING MATERIALS OFFICE

1988

REPORT ON

BRIDGE DECK

WATERPROOFING

BY

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SUMMARY

In 1988, the Ministry of Transportation monitored the thickness of waterproofing membrane placed on bridges under its authority, as well as the quality of the membrane.

Membrane thickness is controlled by an end result specification (ERS) which was introduced in 1986. This specification was expanded in 1987 to include membrane quality.

This report contains a summary of the data assembled and comments on the level of compliance with specified tolerances. Comparison is also made to data of previous years.

Problems with contract administration, improper compiling of "Waterproofing Membrane Thickness Report" forms and "Concrete Product Field Sample Sheets" are discussed.

As a result of an analysis of the contained data, it is concluded that membrane thickness and quality compliance is continuing to improve under end result specifications.

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1 INTRODUCTION

1.1 Acceptance Criteria

Bridge deck waterproofing in 1988 was accepted under an "end result specification" (ERS). This ERS provides for a price reduction or rejection for work which fails to meet specified requirements for material thickness and quality.

1.2 Material Thickness

In 1988, the Bituminous Section of the Engineering Materials Office received 323 waterproofing thickness reports from across the Province, representing 126,630 m^2 of waterproofing. Each report was checked for completeness and accuracy and the data then entered on a micro computer spreadsheet. The micro computer was used to sort, analyze and graphically depict the accumulated data.

1.3 Material Quality

The Concrete Section of the Engineering Materials Office tested 186 samples of hot applied, rubberized asphalt waterproofing membrane in 1988. These samples represent products from four manufacturers and were submitted from contract job sites. The samples were obtained from the contractor's melting kettle so as to be representative of material placed on the bridge deck.

Due to a shortage of laboratory staff, not all samples were tested. A representative number of samples from each contract were randomly selected and tested, and if a sample failed, then all samples from that contract would be tested. In all, about 58% of the samples were tested.

The samples were tested for compliance with six specification requirements:

1.	Cone Penetration	@ 25°C	max.	110	(0.1 mm)
2.	Cone Penetration	@ 50°C	max.	160	(0.1 mm)
3.	Flow	@ 60°C	max.	3	(mm)
4.	Low Temperature Flexibility	@ -25°C		Pass	
5.	Toughness		min.	5.5	(Joules)
6.	Toughness/Peak Load Ratio		min.	0.040	

The test results were entered on a micro computer spread sheet program.

2 DATA ANALYSIS

2.1 Material Thickness

Of the 319 lots reported, 11 were borderline and 5 were rejectable. (Refer to Provincial Highways report EM-79 for acceptance criteria.) Four of the five rejectable lots were actually rejected and repaired by the contractor prior to being retested for acceptance. Two of the repaired lots were acceptable and two were borderline and were subject to a price adjustment factor of 0.99. One of the rejectable lots was left in place because of errors made in contract administration by Ministry personnel which precluded an opportunity for the contractor to make repairs before the pavement was placed.

The overall quality of membrane installation has remained the same over the last two construction seasons with no change in the average thickness or lot standard deviation.

The average thickness is very close to the target of 5 mm and the standard deviation reflects acceptable process control. Table 1 depicts the thickness statistics from 1984 to 1988.

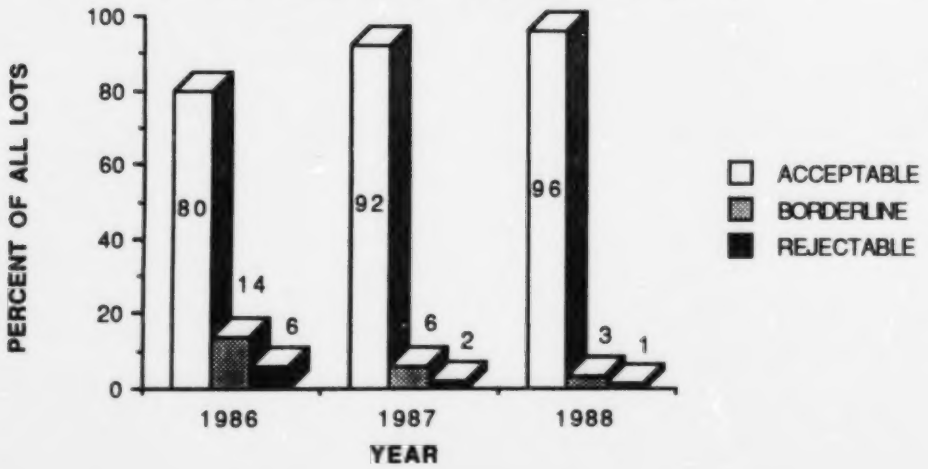
TABLE 1: ANNUAL MEMBRANE THICKNESS SUMMARY

YEAR	NO. OF LOTS	MEAN THICK. (mm)	AVG. LOT ST. DEV.
1984	261	4.7	0.75
1985	306	4.8	-
1986	157	4.9	0.70
1987	254	4.9	0.63
1988	319	4.9	0.63

The larger number of lots for 1985 and 1988 are due to the waterproofing of the new and rehabilitated Burlington Bay Skyway bridges respectively. In 1988 the waterproofing of the Skyway was divided into 75 lots for acceptance. All lots were acceptable with an average thickness of 4.74 mm and an average lot standard deviation of 0.64.

In 1987, close to 92%* of all lots constructed were acceptable, improving to 96% in 1988. This improvement might have been better if it had not been for "new" contractors who had not previously worked under the Ministry's "end result" acceptance system and were not in the habit of exercising process control. Figure 1 depicts the yearly achievement.

FIG. 1: MEMBRANE THICKNESS BY LOTS



* Previously reported erroneously as 97% on page 2 of the text of MI 114, "1987 Report On Bridge Deck Waterproofing" although it was graphically portrayed correctly in Figure 1 and correct in the text on page 6.

Eleven waterproofing contractors shared the work in 1988. Figure 2 demonstrates how the work was divided between the contractors. Of the eleven contractors, five had all lots accepted at full price and six had some borderline or rejectable lots. Figure 3 depicts the relative performance of each contractor (identities concealed).

The contractors with the four lowest average standard deviation (good process control)"A,E,F,K" also had all lots "acceptable".

Individual contractor statistics are presented in Table 2.

FIG. 2: CONTRACTORS' SHARE OF WORK

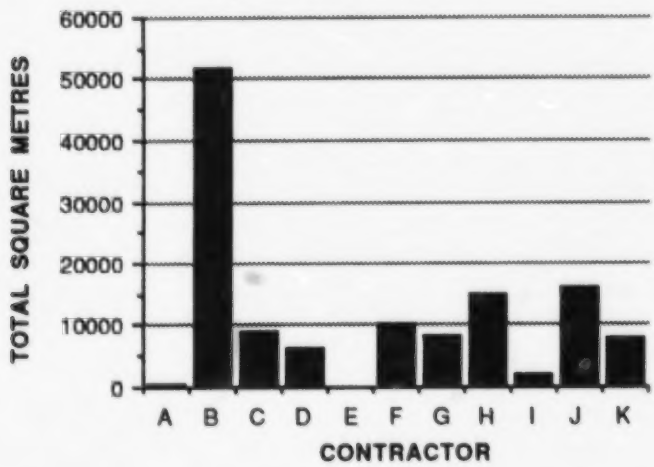


FIG. 3: CONTRACTOR PERFORMANCE

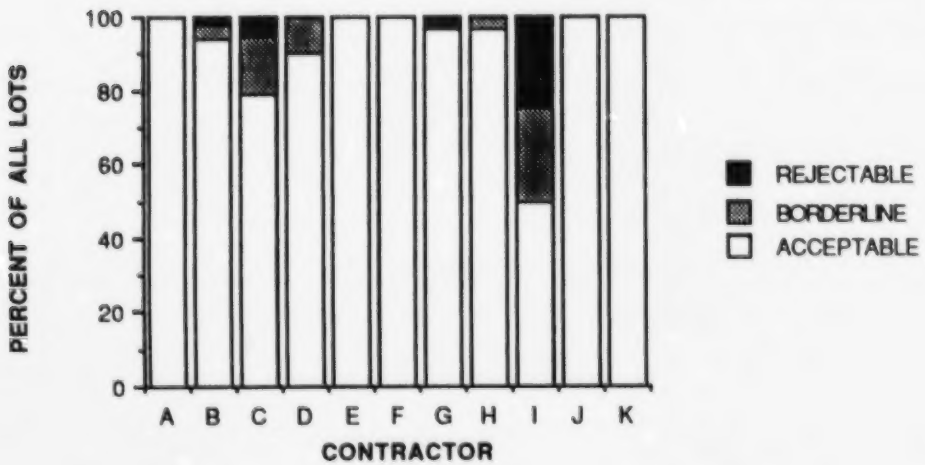


TABLE 2 : CONTRACTORS' STATISTICS

CONTRACTOR	MEAN THICKNESS (mm)	AVERAGE LOT ST. DEV.
A	5.70	0.50
B	4.69	0.64
C	4.80	0.75
D	5.20	0.72
E	5.10	0.45
F	4.90	0.60
G	5.32	0.72
H	5.10	0.62
I	4.53	0.80
J	4.92	0.64
K	4.84	0.49

2.2 Material Quality

One hundred and three of the 186 samples tested were from one manufacturer (A), with the other 83 being divided up between the other three products. The reason for the apparent disproportionate testing is because product "A" had many failures resulting in testing of all the samples from the same contract. Figure 4 demonstrates the distribution of the products on Ministry work.

Seventy seven percent of the samples met all test criteria with 23% failing one or more tests. Forty one samples failed, resulting in a price reduction for the lots represented and one rejectable sample resulted in no payment for the lot. The Price Adjustment Factors ranged from 0.889 to 0.998 with an average of 0.979, excluding the rejectable sample. The level of compliance is less in 1988 than it was in 1987, due mainly to minor failures in cone penetration by product "A". The severity of the failures are significantly reduced from 1987. Figures 5 and 6 demonstrate the proportions of samples failing tests.

Material by the major supplier of membrane to the Ministry, passed all quality tests in both 1987 and 1988 ("B" in FIG. 4 & 6).

FIG. 4: MANUFACTURERS SHARE OF AREA

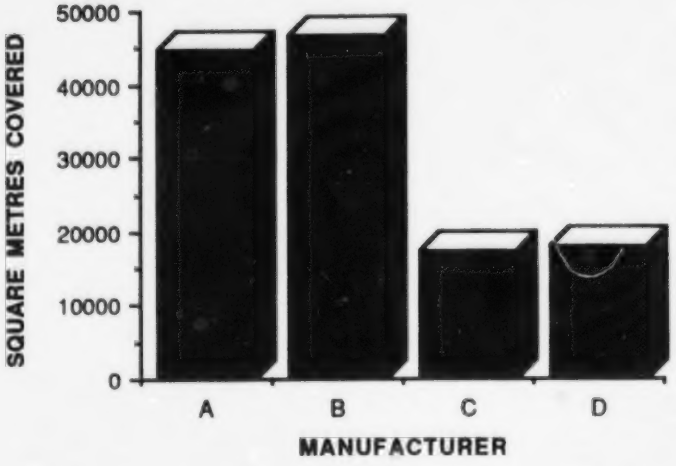


FIG. 5: ASPHALT MEMBRANE QUALITY TESTS

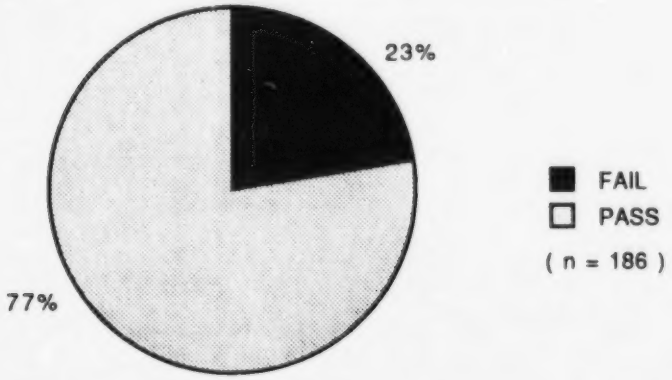
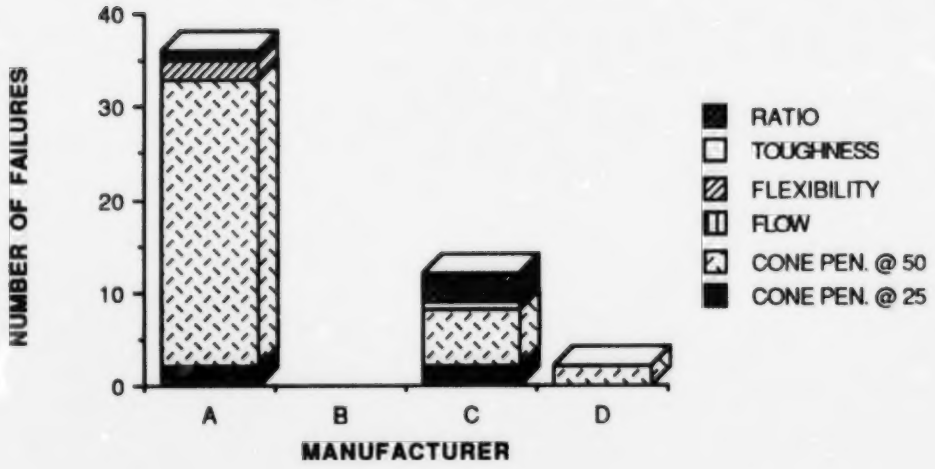


FIG. 6: TEST CRITERIA FAILED



2.3 Material Mass Density

Although not a specification requirement, the mass density of each sample is determined in the laboratory. This mass density along with the other tests can be used to ascertain whether the sample is representative of the material as identified on the sample sheet. Since the various products have different mass densities, it is a useful tool to determine if a sample has been adulterated.

From the mass density of each product, the quantity required to cover a given area may be determined. Table 3 presents the quantity of product required to cover a square metre with 5 mm of membrane based on the mean mass density determinations of the four products supplied to the Ministry in 1988.

TABLE 3 : MATERIAL REQUIRED PER SQUARE METRE OF BRIDGE DECK (5 mm thick)

PRODUCT	kg/m^2
BAKELITE 790-11 *	6.20
BE-RAM BEMALASTIC	7.70
HYDROTECH 6120 BD	6.00
PERMAQUIK 6100 BM	6.15

* Based on the average mass density of samples obtained after August 1st (new formulation).

3 DISCUSSION

3.1 Material Thickness

When the statistical acceptance system involving price adjustment for thickness was first introduced, it was said by some contractors to be too restrictive or even unattainable.

The high level of compliance in 1987 (92% of all lots received full payment) and 1988 (96% of all lots received full payment) demonstrates that contractors can work to the requirements of the acceptance system. The percent compliance will likely improve slightly in 1989 with the "new" contractors gaining experience in exercising process control.

When the statistical acceptance system involving price adjustment for thickness was first introduced, waterproofing contractors were concerned that the rough surface on some older bridges would adversely affect their chances of full payment even with excellent process control.

Over the first two years there were a few decks where Ministry staff employed the price adjustment system and the contractor has claimed it should not have been applied due to excessive roughness of the deck.

The Ministry has made a commitment to improve the surface of a rough existing deck or waive the statistical acceptance with price adjustment in favour of acceptance based on a mean thickness only.

For the 1988 construction season, the Structural Office, in co-operation with the Engineering Materials Office, developed minimum standards for an existing deck that is to be waterproofed, along with criteria for waiving the statistical acceptance system when these standards would not be met. No serious controversy between any Contractor and the Ministry on this issue was reported in 1988.

On one contract, Ministry staff waived the statistical acceptance procedure and counted the number of drums of material used to determine how much material was applied. No thickness measurements were recorded. This is not an acceptable procedure and not in keeping with the policy set out in the "Field Guide For Acceptance of Bituminous Materials".

3.2 Material Quality

Since 47% of the material samples failed one or more tests in 1986, a decision was made to develop a price adjustment scheme for nonconforming materials. The various manufacturers were advised of their products' failures and also that a price adjustment scheme was under development. In March of 1987 a formal presentation was made to the Waterproofing Contractors Association outlining the proposed price adjustment system for membrane quality - the product manufacturers are members of this association.

Contracts awarded after August 1987 contained a special provision which adjusts price for both thickness and quality noncompliance.

Although not fully in effect in 1987, the fact that the Ministry took this price adjustment initiative appears to have had a positive impact on the quality of material applied to bridge decks in that year. The percentage of samples failing any test criteria dropped from 47% in 1986 to 20% in 1987. With the price adjustment component for quality in effect for all 1988 contracts it was expected that quality compliance would significantly improve in 1988. It actually appears worse. This was principally because one manufacturer's product frequently failed marginally the cone penetration requirement at 50° C .

The manufacturer claimed that the reheating of the product in the laboratory caused an increase in penetration which was sufficient to put it out of specification. The Ministry confirmed through laboratory testing that there was an increase in penetration on reheating this particular product. However, it is standard practice to reheat material in the contractor's field kettle and this action could also put the material out of specification. The Ministry has taken the position that no special consideration will be made for this product since all others are subject to the same reheating in the laboratory.

4 FIELD DOCUMENTATION

4.1 Material Thickness

About 80% of the Waterproofing Membrane Thickness Reports contained errors or missing information. This is not much of an improvement from 1987 when about 90% contained errors or missing information. Errors were corrected prior to entry into the computer.

Following are some of the most common errors, and they are the same as reported for the 1987 work.

a. Stages, rather than whole bridge decks, are divided into lots. This results in the same lot number appearing twice for one bridge.

b. The area of a stage or lot is be entered in the space for "Area of Deck".

c. The "brand" name of the membrane used is not recorded in the space for "Membrane".

d. Thickness results are recorded to one decimal place instead of to the closest whole millimetre. This results in an incorrect computation of the standard deviation and may also result in an incorrect mean value.

e. The standard deviation is incorrectly rounded off. It should be rounded to the closest 0.05. Incorrect rounding can make a significant difference in the determination of the payment adjustment factor.

f. The payment adjustment factor is entered as 0 or nil when it should be 1.0. This can lead to problems in determining payment for the lot when coupled with price adjustment for membrane quality.

On one project, an inspector obtained a number of thickness measurements prior to the completion of a lot and subsequently proceeded to other duties, taking the measurements along. Upon completion of the lot a second inspector took the balance of the measurements. The contractor was then permitted to pave the deck. When the two sets of measurements were assembled together and the mean and standard deviation computed it was discovered that the lot was rejectable. Since Ministry personnel had not followed the proper procedures for acceptance as set out in both the contract documents and the "Field Guide For Acceptance Of Bituminous Materials", and the Contractor had no opportunity to repair the lot prior to paving, the lot became the responsibility of the Ministry.

4.2 Material Quality

Many samples were received without the Concrete Products Field Sample Sheet being adequately completed. Field staff should refer to the "Field Guide For Acceptance Of Bituminous Materials", to make sure that all required information is provided with the sample. This information is critical to our data base and to assure that any price adjustment is applied to the correct lot should a sample fail the quality tests.

5 CONCLUSION

The introduction of end result specifications for the acceptance of bridge deck waterproofing has had, and is continuing to have, the desired impact of improving the quality of this important item of work.

Field testing in 1988 indicates 96% of all lots met thickness requirements.

Laboratory testing shows 77% of all samples tested complied for quality.

There are continuing problems with contract administration and documentation.

6 RECOMMENDATION

Quality Assurance staff should review the acceptance procedures for bridge deck waterproofing with the Project Supervisor, prior to commencement of all waterproofing work.

MATERIAL THICKNESS SUMMARY

CONTRACTOR	NO. of LOTS	ACCEPTABLE	BORDERLINE	REJECTABLE	AVE. AREA	TOTAL m2	AVE. THICK.	AVE. ST. DEV.
A	1	1	0	0	236.0	236	5.70	0.50
B	95	91	4	2	543.3	51613	4.69	0.64
C	18	15	3	1	505.3	9095	4.80	0.75
D	20	18	2	0	314.2	6283	5.20	0.72
E	2	2	0	0	68.0	136	5.10	0.45
F	24	24	0	0	424.3	10184	4.90	0.60
G	31	31	0	1	266.4	8258	5.32	0.72
H	34	33	1	0	442.5	15045	5.10	0.62
I	4	2	1	1 *	463.0	1852	4.53	0.80
J	40	40	0	0	406.7	16268	4.92	0.64
K	50	50	0	0	153.2	7660	4.84	0.49
TOTAL	319	307	11	4		126630**		

* Accepted Without Repair

**DIFFERENCE DUE TO AVERAGING AND ROUNDING

SUMMARY OF MATERIAL QUALITY FAILURES

PRODUCT	m2 COVERED	PEN. @ 25	PEN. @ 50	FLOW	FLEXIBILITY	TOUGHNESS	RATIO	TOTAL
A	44661	2	31	0	2	0	1	32.00
B	46798	0	0	0	0	0	0	0.00
C	17380	2	6	0	0	1	3	8.00
D	18134	0	2	0	0	0	0	2.00
TOTAL	126973**	4	39	0	2	1	4	42